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PERIODIC GROWTH OF POLE-SIZED PONDEROSA PINE

AS RELATED TO THINNING AND SELECTED ENVIRONMENTAL FACTORS

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Periodic Growth of Pole-Sized Ponderosa Pine as Related to Thinning and Selected Environmental Factors

by

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[1] Central headquarters maintained in cooperation with Colorado State University at Fort Collins; research reported here was conducted in cooperation with South Dakota School of Mines and Technology at Rapid City.

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James L. Van Deusen

Introduction

Each year about 10,000 acres of ponderosa pine (Pinus ponderosa Laws.) are thinned on the Black Hills National Forest to meet timber stand improvement goals. These thinnings are necessary (Myers and Van Deusen 1960a), and growth of reserved trees increases markedly (Myers 1958, Stuart and Roeser 1944).

Previous research, however, has not revealed how thinning influences the timing and rate of growth for Black Hills pine. Current height and diameter growth of individual trees have not been investigated, nor has there been an attempt to relate tree growth to environmental factors. This Paper describes and compares the weekly and seasonal growth responses of dominant and codominant trees in thinned and unthinned portions of a second-growth stand. It also discusses the relationships between tree growth and the environmental factors of soil temperature and moisture, air temperature, and gross precipitation.

Methods

Study Area and Tree Sample

The two study plots are located on the Black Hills National Forest, on deep soils derived from limestone rocks. The plots are situated on the lower third of a 10 percent slope which has a generally northeast aspect. This area receives approximately 20 inches average annual precipitation. Nearly two-thirds of the annual precipitation normally falls during the growing season, from April to October. Site index, estimated from soil and topography (Myers and Van Deusen 1960b), is 70 feet at 100 years.

Trees in the upper crown classes on the two plots were similar prior to thinning. The original stand on each plot contained about 190 square feet of basal area per acre, but the stand to be thinned had 862 fewer trees per acre, mostly in the 1- and 2-inch diameter classes. One plot was thinned in August 1957; the other was left uncut. Each plot was 0.126 acre and had a 30-foot isolation strip surrounding it. The plots were adjacent on the contour.

Plot and stand characteristics 1 growing season after thinning are given in table 1. The larger average d.b.h. for the thinned plot at the beginning of the measurement period resulted primarily from removal of many small-diameter trees in the thinning operation.

Table 1.--Plot conditions for 70-year-old pole-sized ponderosa pine, Black Hills of South Dakota, at the beginning of the study

Treatment	Plot size	Trees per acre	Basal area	Average d.b.h.
	Acres	No.	Sq.ft. /acre	Inches
Thinned	0.126	476	70.9	5.2
Unthinned	.126	2,838	186.9	3.5

Diameter growth was measured on 22 trees; height growth on 15 (table 2). The behavior of a smaller sample of trees during most of the 1958 growing season was used as a basis for determining sample size. All sample trees were straight-boled, did not lean, had no forks or porcupine damage, and were not visibly affected by insects or diseases. In the unthinned dominant category, every tree that met these requirements was sampled. Sample trees on the thinned plot were either dominant or codominant before as well as after thinning.

Some important and real treatment effects are strongly suggested by the magnitude of many of the differences in time of response or amount of growth. Valid statistical inferences cannot be made, however, concerning differences between beginnings, endings, or amounts of height and diameter growth of the four crown class and treatment categories.

Table 2.--Average heights[1] and diameters[2] of sample trees on the thinned and unthinned plots, Black Hills of South Dakota

Tree class	Height	Trees	Diameter	Trees
	Feet	No.	Inches	No.
THINNED:				
Dominant	40	4	6.8	5
Codominant	39	4	6.2	5
UNTHINNED:				
Dominant	39	3	6.4	4
Codominant	36	4	5.3	8

[1] Averages of values read from a balanced free-hand height-over-diameter curve, based on measurements taken at the start of the 1958 growing season.

[2] Averages of measurements made at the start of the 1959 growing season.

Tree Measurements

Terminal shoot growth was measured weekly during the growing season with an engineer's transit. To assure a constant instrument height for all observations, the transit tripod legs were set on the tops of three driven stakes at each station. Dowels, graduated with 0.5-inch bands, were attached to upper stems of sample trees. Periodic growth values were obtained by subtracting the previous week's reading from the current reading. Interpolations to the nearest 0.25 inch were usually possible. Precise readings were difficult at the beginning and end of the growing season because terminal needles tended to obscure the bud.

Height growth of each sample tree was considered to begin on the date immediately preceding the one on which measurable growth was observed. The average beginning of height growth for the sample trees in each crown class-treatment category on each plot was the observation date which immediately preceded a class average height increase of 0.1 inch or more.

Height growth for individual trees was considered to end on the date when the last increase in leader length was measured. The average date of cessation of height growth for plot sample trees was the last measurement date on which a class average height increased 0.1 inch or more.

Weekly changes in tree diameters were measured with a dial gage dendrometer similar to one described by Daubenmire (1945). A pair of dendrometer points were located on each sample tree at breast height, one on the north side and one on the south side.

All sample tree radii fluctuated early in the spring. Diurnal fluctuations of tree radii may be greater than weekly radial changes during certain times of the year (Kozlowski 1963). Eventually, however, a dendrometer reading for a given point was larger than any previous measurement taken. Thereafter, weekly readings usually showed a steady increase in stem size. The measurement date immediately preceding the one that started a series of continuously increasing radial sizes was defined as the beginning of diameter growth. Radial fluctuations prior to that date were ignored in computing diameter growth. Thus, diameter growth might depend, for a short period, on a net increase in length of only one radius. The phenomenon of different radii at the same height on the same tree beginning growth at different times was also observed by Kozlowski and Bormann (1962).

The average beginning date of diameter growth for all sample trees on a plot was the measurement date immediately preceding an average diameter increase of 0.001 inch or more, with continuous increments following it.

The end of diameter growth for either individual trees or groups was the last observation date on which a diameter increase of at least 0.005 inch was measured. Late-season shrinking and swelling made acceptance of a 0.005-inch increase necessary.

Radial growth measured on the smoothed and glass-covered surface of the bark included size increases due to formation of phloem as well as xylem. At the conclusion of the study, an increment core was extracted directly below each dendrometer point. Cores were kept immersed in water until the yearly xylem increment was measured with a microscope dendrometer. Xylem growth (or ring width) was then converted to percent of total yearly radial increase.

Environmental Measurements

Several environmental factors were measured to provide data that might explain tree responses. Soil moisture and temperature data for depth intervals of 1/4, 1, 2, 3, 4, 5, and 6 feet were obtained in each plot from one stack

of Colman fiberglass sensing units. Inches of moisture in the upper 4 feet of soil was chosen as the most reliable expression of root zone soil moisture. Air temperatures were recorded by a thermograph in a standard U. S. Weather Bureau shelter located in a clearcut plot adjacent to the thinned plot.

Total precipitation was measured with a recording and a storage-type gage, both located in a large opening adjacent to the plots. Throughfall precipitation in each plot was measured by three replicate pairs of storage gages. Each pair of gages was moved systematically among 10 randomly located stations at the end of any week in which the recording gage measured 0.05 inch or more rainfall.

Results and Discussion

Differences in time of beginning and ending of height and diameter growth were common among sample trees within years, as well as from 1 year to the next. Average dates, by plot, of the combined crown class responses, are shown in figures 1 and 4.

The main comparisons in this report involve relationships between upper crown classes on the thinned and unthinned plots. Responses of dominant and codominant crown classes are presented separately to provide a more complete description of tree behavior in thinned and unthinned stands (table 3).

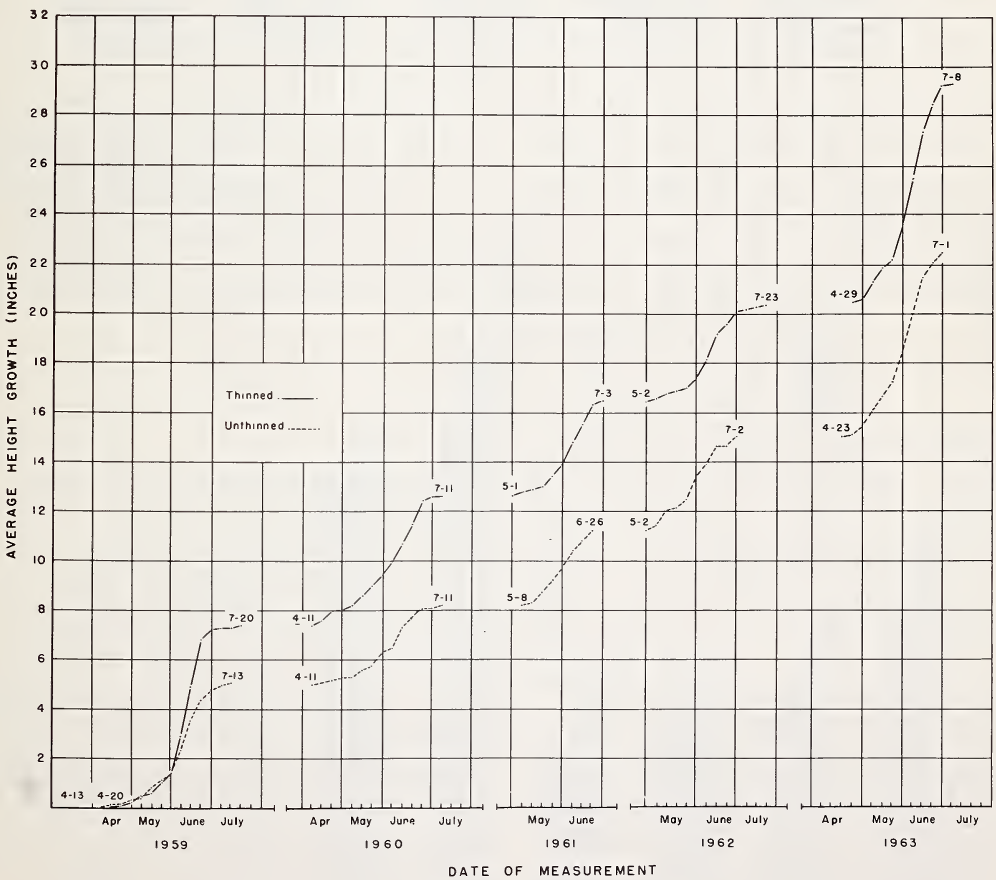

Figure 1.--Cumulative average height growth of thinned and unthinned pole-sized ponderosa pines, 1959-63.

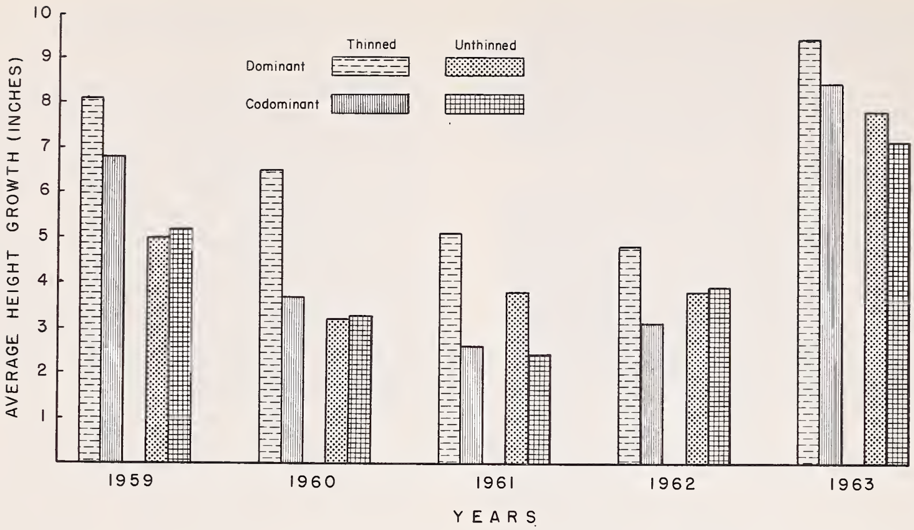

Figure 2.--Average yearly height growth of dominant and codominant ponderosa pines on thinned and unthinned plots, 1959-63.

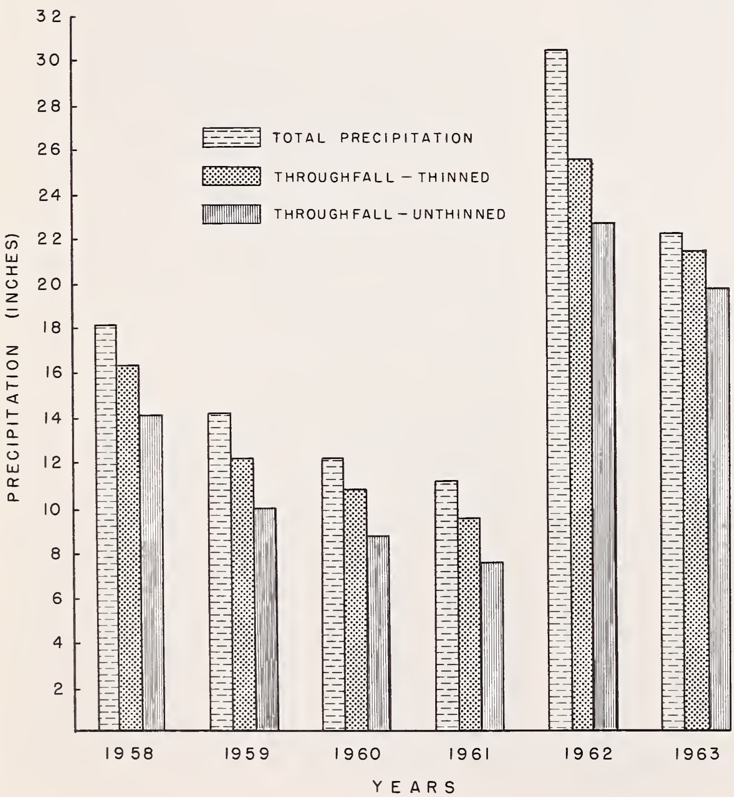

Figure 3.--Total and throughfall precipitation from April 1 to October 1,1958-63. Throughfall for 1961 was computed by regression between periodic total precipitation and throughfall in each plot for the same period in 1960. Correlation coefficients: thinned, r = 0.998; unthinned, r = 0.989.

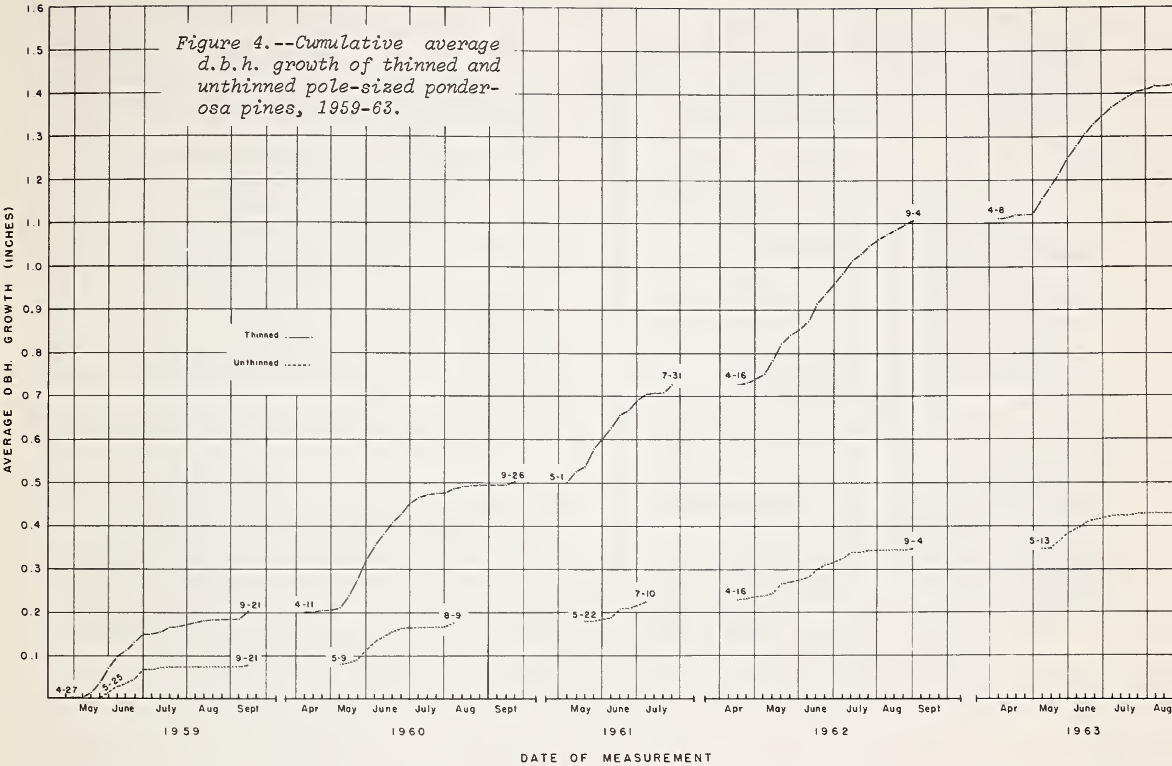

Figure 4.--Cumulative average d.b.h. growth of thinned and unthinned pole-sized ponderosa pines, 1959-63.

Height Growth

Average height growth was always greater for trees in thinned than in corresponding unthinned stands (fig. 1), although in 1961 the average difference was only 0.1 inch.

Length of the height growth period was similar each year on the two plots. Only in 1962 did the beginning or ending dates differ by more than a week. That year, trees in thinned stands continued growing 3 weeks longer than those in unthinned stands.

There was a general decrease in height growth each year from 1959 through 1961 (fig. 2) as precipitation (fig. 3) decreased. Although precipitation increased in 1962 to more than 2-1/2 times the 1961 total, height growth did not respond to the more abundant moisture until 1963. Such leader growth behavior is expected, since currently produced photosynthates do not influence height growth nearly so much as those manufactured in the previous year (Kramer and Kozlowski 1960).

Trees in the thinned stand, as a group, grew 6.8 inches taller (1/3 more) in the 5 years than those in the unthinned stand. This suggests that competition among trees in the unthinned stand was so severe that their height growth would not be a reliable indicator of site quality. Average height of dominant and codominant trees in the unthinned stand indicated a site index of only 55 (Hornibrook 1939), in contrast to the index of 70 estimated from soil and topography.

In all years except 1961, trees from the two crown classes on each plot differed by no more than 8 days in average date of beginning or ending of height growth. In 1961, dominants started height growth an average of 18 days earlier than codominants in the thinned stand.

On the thinned plot, height and diameter growth began, on the average, at the same time in 2 of the 5 years—1960 and 1961. In 1962 and 1963 diameter growth, on the average, began 3 weeks sooner than height growth. Dimock (1964) observed similar results for Douglas-fir

Table 3. --Dates of beginning and ending of height and diameter growth in thinned and unthinned stands of pole-sized ponderosa pine

Type of stand and individual tree number	1959		1960		1961		1962		1963	
	Began	Ended	Began	Ended	Began	Ended	Began	Ended	Began	Ended
HEIGHT GROWTH										
THINNED:										
Dominants										
Tree 15	April 20	July 1	April 18	July 5	May 1	July 3	May 28	July 16	May 6	July 1
19	April 27	July 20	April 18	July 18	May 1	July 10	May 2	July 23	May 6	July 15
35	April 27	July 1	April 11	June 27	May 1	July 3	May 7	July 2	April 29	July 1
45	May 5	July 6	May 9	June 27	May 22	June 26	June 4	July 9	May 6	July 8
Average	April 27	July 7	April 21	July 4	May 6	July 3	May 18	July 12	May 4	July 6
Codominants										
Tree 7	April 20	July 1	April 11	June 27	June 5	June 26	May 14	June 20	April 29	July 8
50	April 27	July 6	([1])	July 5	May 8	June 26	May 7	July 23	April 29	July 1
9	May 5	July 13	April 18	July 11	May 29	June 26	May 28	July 2	May 6	June 24
48	May 18	July 1	May 9	July 11	May 22	July 3	May 21	July 2	May 6	July 15
Average	May 3	July 5	April 23	July 6	May 24	June 28	May 17	July 4	May 3	July 4
UNTHINNED:										
Dominants										
Tree 218	April 27	July 13	([1])	July 11	May 8	July 3	May 2	July 2	April 23	July 1
416	April 27	July 1	May 9	June 27	May 17	June 26	May 7	July 2	May 6	July 1
367	April 27	June 23	April 11	June 27	May 8	June 26	May 2	July 2	April 29	July 8
Average	April 27	July 2	April 25	July 2	May 11	June 28	May 4	July 2	April 29	July 3
Codominants										
Tree 233	April 13	July 6	April 11	June 27	May 8	June 26	May 2	July 2	April 29	July 1
118	April 20	July 1	April 18	July 25	May 17	June 12	May 7	July 2	April 29	July 1
278	April 27	July 13	May 9	June 27	May 22	July 3	May 2	July 2	April 23	June 24
338	May 5	July 1	April 18	July 11	May 17	June 26	May 2	July 9	May 6	July 1
Average	April 24	July 5	April 21	July 8	May 16	June 24	May 3	July 4	April 29	June 29
DIAMETER GROWTH										
THINNED:										
Dominants										
Tree 35	April 27	Sept. 21	May 2	Sept. 26	April 25	Oct. 9	April 16	Sept. 17	April 8	Sept. 3
19	April 27	Sept. 21	April 5	Sept. 26	April 25	Oct. 9	April 16	Oct. 2	May 6	Sept. 3
1	April 27	Sept. 21	May 2	Sept. 26	May 8	Oct. 9	April 23	Sept. 17	May 6	Sept. 3
15	May 11	Sept. 28	May 2	Sept. 26	May 8	Oct. 9	April 23	Sept. 24	April 8	Sept. 3
45	May 11	Sept. 28	May 2	Sept. 26	May 8	Oct. 9	April 23	Oct. 8	May 6	Sept. 3
Average	May 3	Sept. 24	April 27	Sept. 26	May 3	Oct. 9	April 20	Sept. 26	April 25	Sept. 3
Codominants										
Tree 50	April 27	Sept. 21	April 5	Sept. 26	May 8	Oct. 9	April 16	Sept. 17	April 8	Sept. 3
7	May 11	Sept. 28	May 2	Sept. 26	May 8	July 31	April 23	Sept. 4	April 15	Sept. 3
9	May 11	Sept. 21	April 18	Sept. 26	May 8	July 31	April 23	Sept. 24	April 29	Sept. 3
10	May 11	Sept. 28	May 2	Sept. 26	May 8	July 31	April 23	Oct. 2	May 6	Sept. 3
48	May 11	Sept. 21	May 2	Sept. 26	May 8	July 31	April 16	Sept. 17	May 6	Sept. 3
Average	May 8	Sept. 24	April 24	Sept. 26	May 8	August 14	April 20	Sept. 19	April 25	Sept. 3
UNTHINNED:										
Dominants										
Tree 416	May 18	Sept. 28	May 9	Sept. 26	May 17	July 31	April 16	Oct. 8	May 13	Sept. 3
367	May 18	Sept. 21	May 9	August 9	May 22	Sept. 25	April 16	Oct. 8	May 6	Sept. 3
390	May 25	Sept. 28	May 9	August 9	May 17	July 31	April 16	Oct. 8	May 13	Sept. 3
218	May 25	Sept. 21	May 16	August 9	June 5	July 31	April 16	Oct. 8	May 13	Sept. 3
Average	May 21	Sept. 24	May 11	August 21	May 23	August 14	April 16	Oct. 8	May 11	Sept. 3
Codominants										
Tree 118	May 18	Sept. 28	May 9	August 9	June 5	July 31	April 16	Oct. 8	May 13	Sept. 3
278	May 25	Sept. 28	May 9	August 9	May 22	July 31	April 16	Oct. 8	May 13	Sept. 3
317	May 25	Sept. 28	May 2	Sept. 26	May 29	July 31	April 16	Oct. 8	May 13	Sept. 3
103	May 25	July 20	May 9	Sept. 26	June 5	July 31	April 16	Oct. 8	May 13	Sept. 3
189	May 25	Sept. 28	May 9	August 9	June 5	July 31	April 16	Oct. 8	May 13	Sept. 3
233	May 25	Sept. 28	May 9	August 9	June 5	July 31	April 16	Oct. 8	May 13	Sept. 3
372	May 25	Sept. 28	May 9	Sept. 26	June 5	July 31	April 16	Oct. 8	May 13	Sept. 3
338	May 25	Sept. 28	May 23	August 9	June 26	July 10	April 16	Oct. 8	May 20	Sept. 3
Average	May 24	Sept. 19	May 11	August 27	June 5	July 28	April 16	Oct. 8	May 14	Sept. 3

[1] Leader damage prevented observation of beginning height growth date.

in Washington. Conversely, in 1959 height growth began, on the average, a week before diameter growth.

On the unthinned plot, height growth began from 3 to 6 weeks earlier than diameter growth in 4 out of 5 years. The exception was 1962, when diameter growth started, on the average, 3 weeks before height growth.

Diameter Growth

At breast height.—Thinned dominants and codominants, as a group, grew more in diameter each year than their unthinned counterparts (fig. 4). Thinned sample trees, during 4 of the 5 years, began growth at breast height from 3 weeks to a month earlier than unthinned sample trees. In only 2 years, however, did the thinned trees continue growth longer in the fall than unthinned trees. These 2 years, 1960 and 1961, were the last 2 in a series of 4 that had progressively less precipitation (fig. 3).

The average diameter growth was always greater for thinned than for unthinned trees during the period of most rapid increase. By the end of the fifth year, thinned trees had grown an average of 1 inch more than unthinned trees, or more than three times as much. Thinned trees grew for a much longer time and at a higher rate in both favorable and dry years.

Dominant trees always grew more, in the same length of time, than codominants on a given plot (fig. 5). The two classes began and ended growth within a week of one another in all years except 1961. In that year, thinned dominants averaged nearly 2 months more of diameter growth in the fall than thinned codominants; unthinned dominants began growth 2 weeks earlier and continued 2 weeks longer than unthinned codominants.

The similarity in rates of d.b.h. growth in the thinned and unthinned stands in 1959 (fig. 4) probably indicates that the thinned trees had not yet expanded their crowns and root systems enough to take full advantage of the increased growing space. By 1960 the response to thinning was more typical, despite mounting moisture stress.

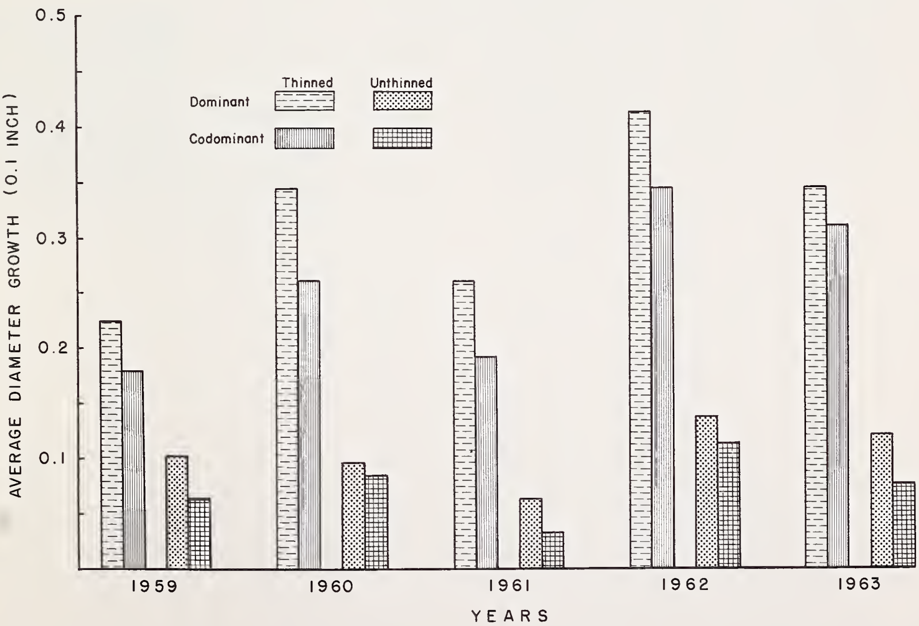

Figure 5.--Average yearly d.b.h. growth of dominant and codominant ponderosa pines on thinned and unthinned plots, 1959-63.

Ring width at breast height.—Xylem (wood) made up a slightly greater proportion of the annual diameter growth of thinned than of unthinned trees—83 percent versus 76 percent. The remaining diameter growth was phloem (bark).

Vertical distribution of increment.—Ring widths were measured at the close of the study on cores extracted at 4-foot intervals from two dominant trees, one thinned and one unthinned. Vertical distribution of increment was similar to that observed by Myers (1963). Figures 6 and 7 illustrate the three main points:

1. Both the thinned and unthinned trees grew rapidly in the upper stem. The unthinned tree increased in diameter more in the upper stem than anywhere else on the bole. This is the common growth pattern that causes the boles of crowded trees to approach a cylindrical form.
2. Growth of the thinned tree increased throughout the stem, but the increase was greatest on the lower stem and at the base. This is the frequently observed tendency of thinned trees to strengthen their lower boles and root zones, which is attributed to an increased stimulus from wind exposure.
3. The thickness of annual growth layers was influenced by current precipitation in addition to thinning treatment.

Tree Growth and Environmental Factors

None of the environmental factors measured in this study, alone or in combination, could be consistently related to beginning or ending of height and diameter growth, nor to the course of growth during the season.

In some instances, a trend based on 2 or 3 years' performance would seem evident between beginning or ending of growth and some

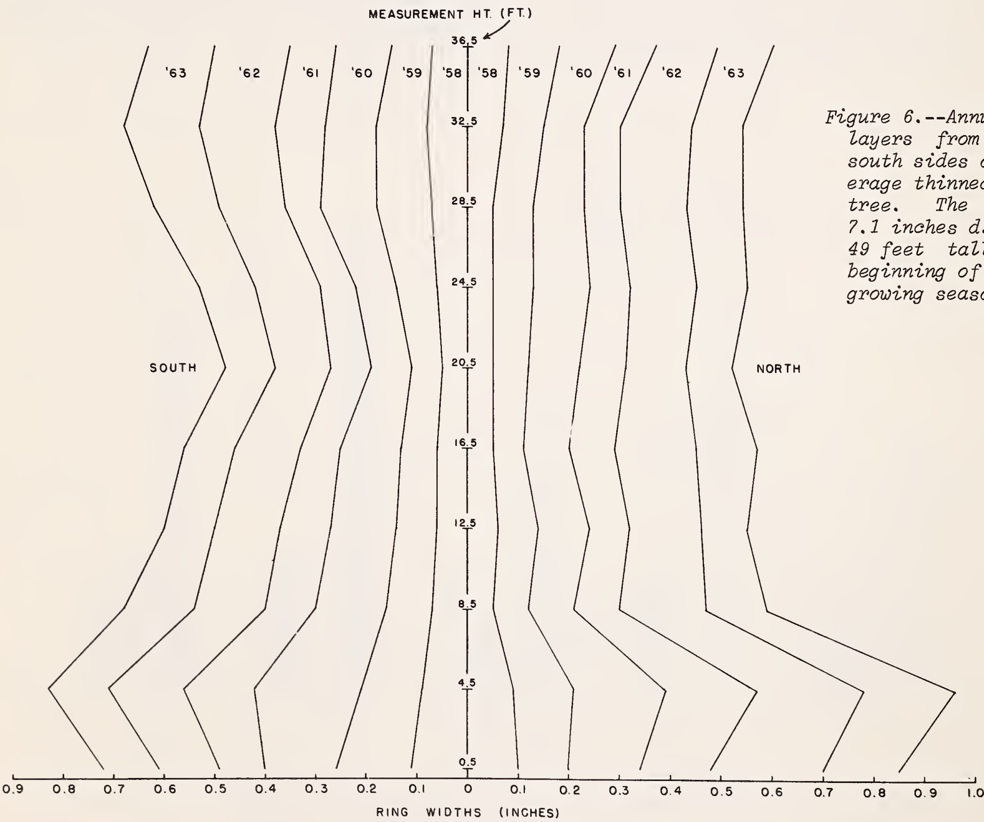

Figure 6.--Annual growth layers from north and south sides of an average thinned dominant tree. The tree was 7.1 inches d.b.h. and 49 feet tall at the beginning of the 1958 growing season.

one or a combination of measured environmental factors. In the next year or two, however, the trees responded differently.

Initiation of growth.—Air temperature has been found to influence the start of height and diameter growth (Turner 1956, Haasis 1934, MacDougal 1938, Hess 1960), but only an indirect, and weak, relationship with soil temperature was found in this study. Neither height nor diameter growth started, on the average, until after the first foot of soil had warmed to above freezing. Growth did not always begin, however, as soon as above-freezing temperatures were reached at that level.

Height and diameter growth on the unthinned plot frequently began when soil moisture was extremely limited. From 1959 through 1962, growth began when soil moisture at all sampling points below 3 inches was less than the calculated wilting point.

Growth during the season.—Periodic changes in diameter, especially during times of limited moisture availability, showed a fairly consistent relation to current precipitation. Figure 8 shows cumulative changes in diameter for representative trees on the two plots during years of below-average and above-average precipitation. The unthinned tree, particularly in 1961, exhibited mid- and late-season shrinkage and swelling which coincided, roughly, with wet and dry periods. This pattern was less pronounced for the thinned tree. When precipitation was generally adequate for continued growth, as in 1962, diameter shrinkages were not common, even late in the growing season.

Much of the height and diameter growth on both plots during 1960 and 1961 occurred when moisture at nearly all measured levels in the first 54 inches of soil was below the wilting point. In fact, soil moistures at the sampling points in the first foot of soil remained below

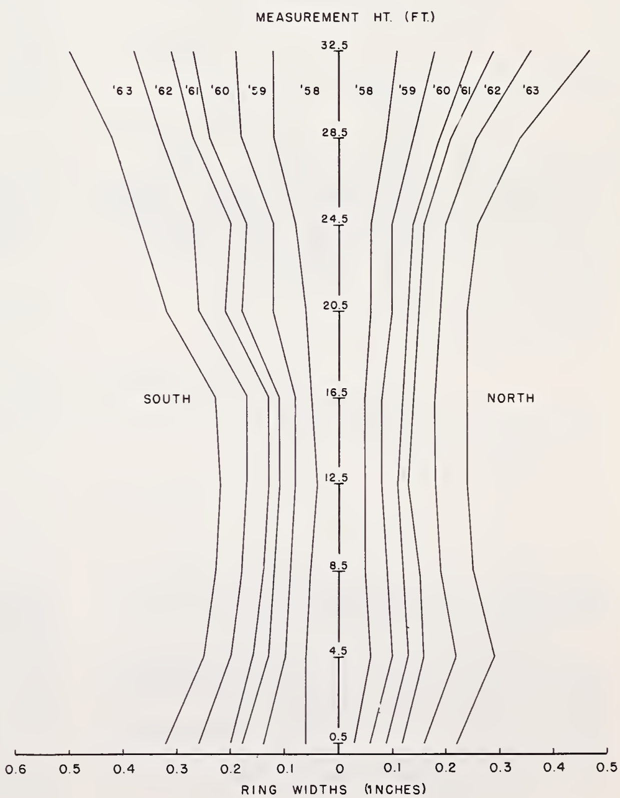

Figure 7.--Annual growth layers from north and south sides of an average unthinned dominant tree. The tree was 7.7 inches d.b.h. and estimated to be 43 feet tall at the beginning of the 1958 growing season.

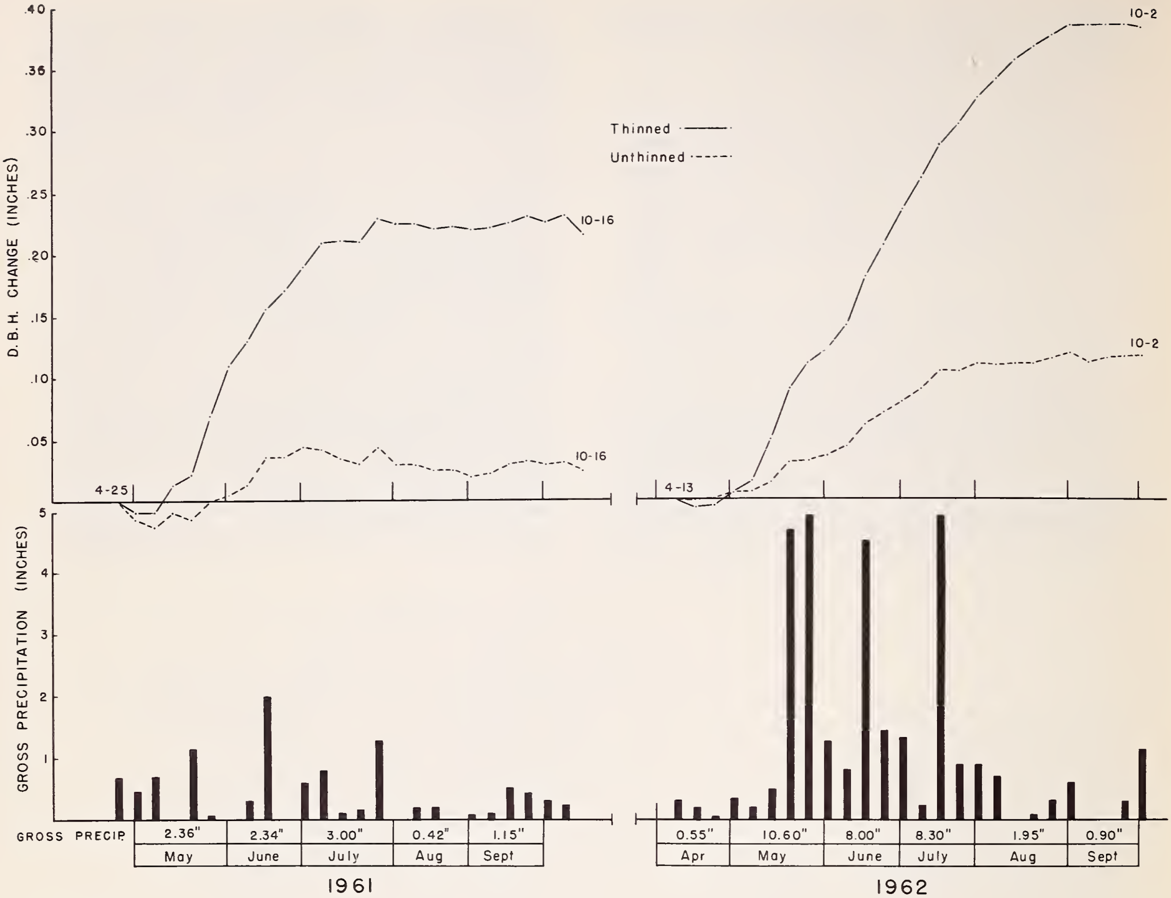

Figure 8.--Cumulative changes in d.b.h. during the 1961 and 1962 growing seasons for an average thinned and unthinned pole-sized ponderosa pine. Also shown is periodic gross precipitation for those seasons.

the wilting point in both plots during the midsummer to fall period in both 1960 and 1961.

Cessation of growth.—Cessation of diameter growth among trees on the unthinned plot appeared to be roughly regulated by soil moisture. As the soil moisture shortage in the unthinned plot became more acute each year from 1959 through 1961, diameter growth ended earlier in the season (fig. 4). Then in the wet years of 1962 and 1963, diameter growth of all unthinned sample trees continued until early September. No consistently similar relationship was found in the thinned plot, perhaps because soil moisture was more plentiful every year in this plot.

The relatively uniform time of height growth cessation on both plots within and between

years, despite wide yearly differences in most measured environmental factors, indicates that this response may be regulated internally, or by external factors not measured in this study.

Summary and Conclusions

Two plots of pole-size Black Hills ponderosa pine, one thinned and one unthinned, provided information on weekly and seasonal height and diameter growth for dominant and codominant trees. Measurements and observations were made for a 5-year period. Environmental factors were measured to try to explain the "why" of growth responses. These factors included air temperature measured in an adjacent opening, total and throughfall precipitation, and soil moisture and temperature.

Although thinned and unthinned sample trees usually began and ended height growth together each year, the greater amount of height growth achieved by thinned trees is of practical importance. If thinned trees continued to outgrow unthinned trees by 7 inches each 5 years, in only 60 years (half the current rotation period) they would be 7 feet taller than the unthinned trees.

Diameter growth began earlier on the thinned plot in 4 of the 5 years. The 3- to 5-week earlier start by thinned trees meant that they were growing actively through a greater part of the period of most abundant moisture than the unthinned trees.

The earlier start and faster growth during the main part of the growing season accounted for the markedly greater diameter growth of thinned trees. If this faster growth could be maintained or further increased by regular thinnings, it should be possible to grow trees to sawtimber size in the Black Hills on a shorter rotation than is now planned. The amount and timing of growth responses by other trees of upper crown classes are expected to be similar under comparable stand conditions on high-quality sites throughout the Black Hills.

Vertical distribution of increment on a dominant tree in a thinned and an unthinned plot differed mainly in that the thinned tree added much more wood near the base. Increment added to the lower bole of the thinned tree was laid on at no apparent expense to wood production higher on the stem.

Xylem (wood) made up a greater percentage of the 5-year outside bark diameter growth for thinned trees than for unthinned trees. Both xylem and phloem (bark) production throughout the study was greater, on the average, among thinned trees.

Environmental factors, singly or in combination, were not generally helpful in explaining when height and diameter growth began or ended. On the other hand, periodic changes in diameter of trees growing under a moisture stress were closely related to periodic precipitation.

Individual trees varied widely in the timing of their growth responses, within as well as between years. With such great individual variation, it was not possible to show consistently good relations between single or combined environmental factors and specific growth responses.

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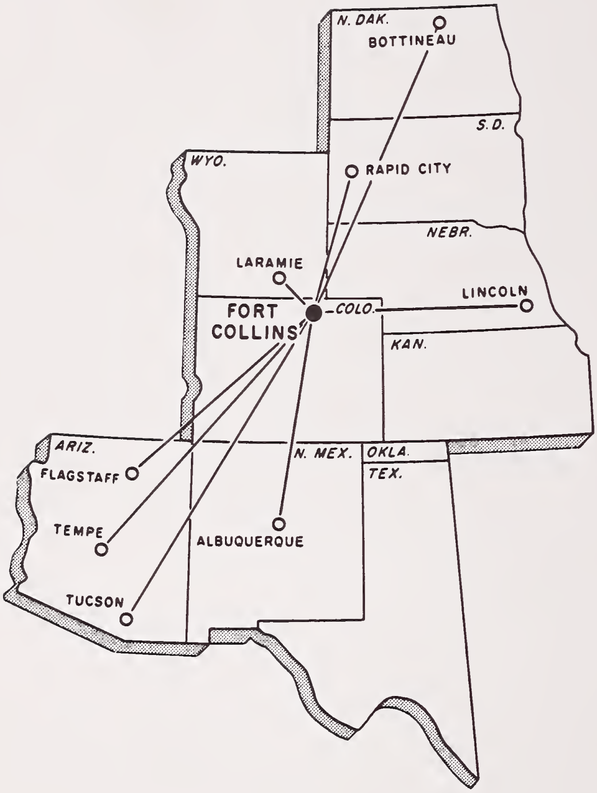
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